ECOLOGICAL INVESTIGATIONS OF THE MACROALGAE IN BISCAYNE BAY AND CARD SOUND, FLORIDA
I. PRELIMINARY RESULTS OF THE RED ALGAL COMPLEX

Anitra Thorhaug and Julio Garcia-Gomez
Department of Microbiology
School of Medicine
University of Miami
Miami, Florida

[Restored and transferred to electronic form by A. Cantillo (NOAA) in 1999. Original stored at the Library, Rosenstiel School of Marine and Atmospheric Science, University of Miami. Minor editorial changes were made.]

The ecology of macroalgae has enjoyed scant attention in tropical and subtropical estuaries. Most estuaries were previously considered to be based on a phytoplanktonic food chain. A recent review of phanerogam populations has indicated large benthic grass communities in such diverse estuaries as Puget Sound and Beaufort North Carolina (reviewed in Wolfe, Thayer and Williams, 1972). In a south west Florida estuary, the mangrove detritus was found to be a major source of plant material for the food web (Odum, 1970; and Heald, 1971).

The Biscayne Bay - Card Sound estuarine system has been investigated during the past two years for the effect of heated industrial effluents. Quantitative estimates of both a stressed area and an unstressed area indicate that the dominant phanerogam *Thalassia testudinum* Koenig, is extremely productive in areas near to shore and has relatively high productivities in the central bay. This study indicated that quantitatively *Thalassia* contributed more plant material to the food web than either the phytoplankton or the mangrove population in this area (Thorhaug and Stearns, 1972). However, the role of the benthic macroalgae and the macroepiphytes remains totally unknown. Two pieces of information imply that the red algal complex, chiefly, *Laurencia poitei* (Lamouroux) Howe, with several other red algal species may be of particular importance in this estuary. First, trawling studies conducted over the past three years in this estuary (Roessler, 197x) and in an estuary to the south (Tabb and Manning, 1961; Tabb *et al.*, 1962) have found a high standing crop of the red algal complex, as well as a high correlation between the catch of animals and the amount of vegetation. These estuaries are relatively shallow (Biscayne Bay, an average of 6 feet, Card Sound, 10 feet) with topological features to provide shelter for the many, small species found herein. The second piece of information is a study by Humm (1964) who identified the epiphytes found on the dominant sea grass *Thalassia testudinum*. Of the 113 species found, Humm estimated that 60% were red algae, and then suggested that these may be of significance to the total productivity of the estuary. A second investigation of an estuary off the northern coast of Brazil (Ferreira-Correia, 1969) has found a high red algae epiphyte population on *Digenia simplex* (Wulfen) C. Agardh

The phycological literature offers us little beyond these data. Early work included much taxonomy (3, 5, 7, 8, 11, 12, 15, 23, 28, 29, 30, 31) several studies of thallus growth and several photosynthetic investigations of temperate forms (4, 15).

The only known tropical estuarine physiology was a part of a larger study by Biebl (1962 a and b) to determine short term upper lethal limits of many algae in Puerto Rico.

To investigate the role of the red algal complex in the ecology of Biscayne Bay - Card Sound estuarine system, laboratory and field studies have been conducted over the past nine months.

METHODS

Laboratory

Specimens were collected via SCUBA gear, cleaned thoroughly of animals and debris, then rapidly transported to the laboratory with air-bubbling and cool temperatures. The most healthy of these were again cleaned in running seawater and separated into single strands which averaged 20 cm in length. These were cleaned epiphytes and strung onto monofilament 3 per string, anchored by a bottle containing sand. The indoor tanks had running sea water pumped from Bear Cut to the large containing tank on the roof and gravity fed through polyvinyl chloride pipes to our tanks. There it passed through a filter with spun dacron and an ultra violet light. This overflowed into the tank at a rapid rate. Lighting was 20 watts Grolux (27% of natural daylight). The outdoor tank was 4 feet by 4 feet by 2 feet. The running sea water design was similar to the indoor tanks. Light was filtered out by 73% greenhouse screening. Two submersible pumps were used to increase the circulation within the tank. This served to curb epiphytes and enhanced growth.

The first measure of growth was to mark the tips of a specimen with plastic tape and to measure the amount of growth from the tape per week. This measured only tip growth. Secondly, specimens were drawn weakly on large mm^2 graph paper with magnification by a camera lucida. This measured total growth of tips and lateral papillae. Thirdly, specimens were allowed to drip excess water for 30 seconds then inserted into a folded clear acetate sheet which placed on 20.3 x 25.4 cm Kodak photographic paper. This was exposed to sunlight for 1 minute, then the paper was immersed in Hypo solution, washed with water and dried. The total plant was measured from this photoproof paper by using a Swivel handled map measurer. Dry weights of 50 specimens of various sizes were carried out by blotting the sample for 30 seconds on absorbent paper, then weighing and drying at 110 °C for 3 days.

Field procedures

Eight stations in Turkey Point and 16 stations in Card Sound were chosen from a grid. Aluminum frames were placed randomly at each station of one square meter. Each was subdivided into quadrants with 1/4 inch polyethylene cord. The percentage of each quadrant covered with red algal species was recorded as well as any unusual events such as epiphytes and gamete formation. Photographs were taken monthly of the algal squares.

Trawl survey

This work was conducted by Dr. Martin A. Roessler. Seven trawl samples were taken at each of the trawl stations at monthly intervals. A 3-meter foot rope length otter trawl lined with 0.63-mm bar mesh was used for all samples. The tows were made with the wind and the net was emptied into wash tubs at the completion of each tow. After seven tows were completed the contents of each tub were rough sorted. The kind and weight of vegetation were recorded and the animals preserved in a 10 percent formalin solution.

Day catches were compared to night catches with a non parametric paired T test using each species taken by trawling at 20 stations. Night samples were collected within 24 hours of the day samples. Five stations were sampled each month for 4 months. Two tows were made at each night station and those were compared with 2 daylight tows which had vegetation catches similar to the night tows.

Aerial photography methods

The western half of Card Sound, including the mangrove shoreline, has been photographed monthly since May 1971 (weather permitting). Prior photographs were also taken in August and November 1970. These aerial photos were obtained using a U.S. Coast Guard HH-52 helicopter from an altitude of 1500-2000 feet. In order to keep distortion as low as possible, the " look angle" was within 30° to 40° of vertical. The preferred time was 3 hours after sunrise, which minimized water surface glare and atmospheric haze.

Photographic equipment consisted of a hand-held 35 mm Nikon camera with a 28 mm Nikon lens. The wide acceptance angle of the 28 mm lens as compared to a 50 mm lens allowed more area to be covered at lower altitude. A Nikon polarizing filter was essential to reduce the effect of atmospheric haze and improve water penetration.

The preferred film was RMS 404 (Ektachrome X, daylight type in bulk form). There was a loss of 2 f stops when using a polarizing filter, and a high shutter speed (at least 1/125 sec) was needed to eliminate the effects of aircraft vibration. The ASA rating for the film was listed as 64; however, exposure at ASA 100 with normal E-4 processing produced better color saturation. A typical exposure for bright sunny days was 1/12S sec at f8.

FIELD RESULTS

There were several preliminary results from field observations and trawling. The descriptive results from the unstressed estuary of Card Sound will be given first and then the quantitative measurements of standing crop in various parts of the Sound and the monthly variation. Then the quantitative results from the heat stressed area of Turkey Point will also be discussed, then the laboratory growth data.

Card Sound

Descriptive ecology

The red algal complex in Card Sound has one dominant species, *Laurencia poitei* which is far more abundant at most times than any of the others. This alga lives attached to blades to *Thalassia*, rocks, shells, stones, and other animal substrates such as sponges or alcyonarians. It also is very prolific in its unattached state. Observations by SCUBA during various storm periods show that high currents or other abrasion such as animal predation can break the thallus of *Laurencia* from its attachment, leaving it free to be moved by currents. These fragments of the thallus tend to collect in areas of high alcyonarian or *Thalassia* population, which then entwine into mats of many feet in diameter and sometimes mats several feet in volume of the water column. The mats are also collected in areas of less current flow such as behind small islands of Arsenicker and Pumpkin Keys. The mats can be seen from aerial photographs to align with the predominant water currents, and have been used by the physical oceanographers as current indicators. The red algal mats on the western half of Card Sound align in a north-south pattern of rows resembling the Langmeir windrows of the Sargasso Sea. On the eastern half of the Sound the mats are far more random in pattern, which may be accounted for by the tidal flushing through Angel Creak of the eastern half of the Sound. Pumpkin Key, on the eastern half acts as a collector of *Laurencia* and has a large population of it.

The attached stage has been reported to have a sexual stage, we have no observations thus far for a sexual stage in the unattached form.

The other major components of the red algal complex *Laurencia papillosa*, *L. obtusa*, *Dasya pedicellata*, *Gracilaria verrucosa*, and *Acanthophora spicifera* were present. Of these *Digenia simplex* is the most prevalent. This alga growths attached on other algae principally and on rocks or shells. At certain times, large mats of this alga are free floating in Cart Sound. Often *Batophora oerstedi*, a Chlorophyte is found mixed in these mats. Rather infrequently,

Acetabularia crenulata is also found in these mats. These two Chlorophytes have short life spans and prolific swarmers.

QUANTITATIVE RESULTS

The results of two years of trawling surveys show the seasonal pattern of the red algal complex (Figure 1). This shows a clear peak of abundance of standing crop for the late fall 1970, with a low in July, and August. In late fall 1971 there was an increase in standing crop, however, the increase was not as great as in 1970. In April 1972, the Florida Power and Light Company canal to Card Sound was opened, and effluent from the two fossil fuel plants were released into Card Sound. Therefore, the data after this date is difficult to interpret as present or to compare with data from the previous year. However, July values from 1972 appear low as do July-August values from 1971.

The aereal distributions of the red algal complex is seen in Figure 2. The mean monthly standing crops show a low abundance near the mouth of the model land canal where extremes in salinities have been noted (Thorhaug and Stearns, 1972). In the area south of Card Bank there is extremely sparse *Laurencia* on infrequent occasions, with no *Laurencia* the rest of the time. This area is one of high silt and a low energy exchange. The predominant current in the western half of the Sound is toward the north, so that unless unusual wind conditions occurred the water would tend to carry the red algal mats toward the north, allowing little to enter into Card Bank. A seasonal salinity barrier occurs down the middle of the Sound separating the western half from the eastern half. This further restricts the appearance of red algae across Card Bank. The area in the western mid-Card Sound is relatively abundant in the red algal complex. This is in contrast with the *Thalassia* population which is relatively sparse in the mid-Sound, where the bed rock out-crop probably limits its growth (Thorhaug and Stearns, 1972). The low values at the extreme north station are not indicative of the entire region, but rather are biased by the very near shore trawling. Diving observations at that station indicate a far higher population than the rest of the stations. The fixed diving squares were further from shore than the trawling stations and consistently showed high *Laurencia poitei* mats. Patchiness from station to station was marked as was the amount of change from month to month. This was seen for both diving data and trawling. One generalization from the diving observations is that the greater population of the red algae were free floating.

Aerial photography substantiated most of these above observations. Clear windrows of *Laurencia* could be seen under various wind conditions (Figure 3). These windrows were examined by air and SCUBA ground truth and found to be mats dominated by *Laurencia* and about 6 feet in diameter. The eastern aide of the Sound was less abundant in the red algal complex with the exceptions of a prolific station around Pumpkin Key. Few specimens were collected very close to shore.

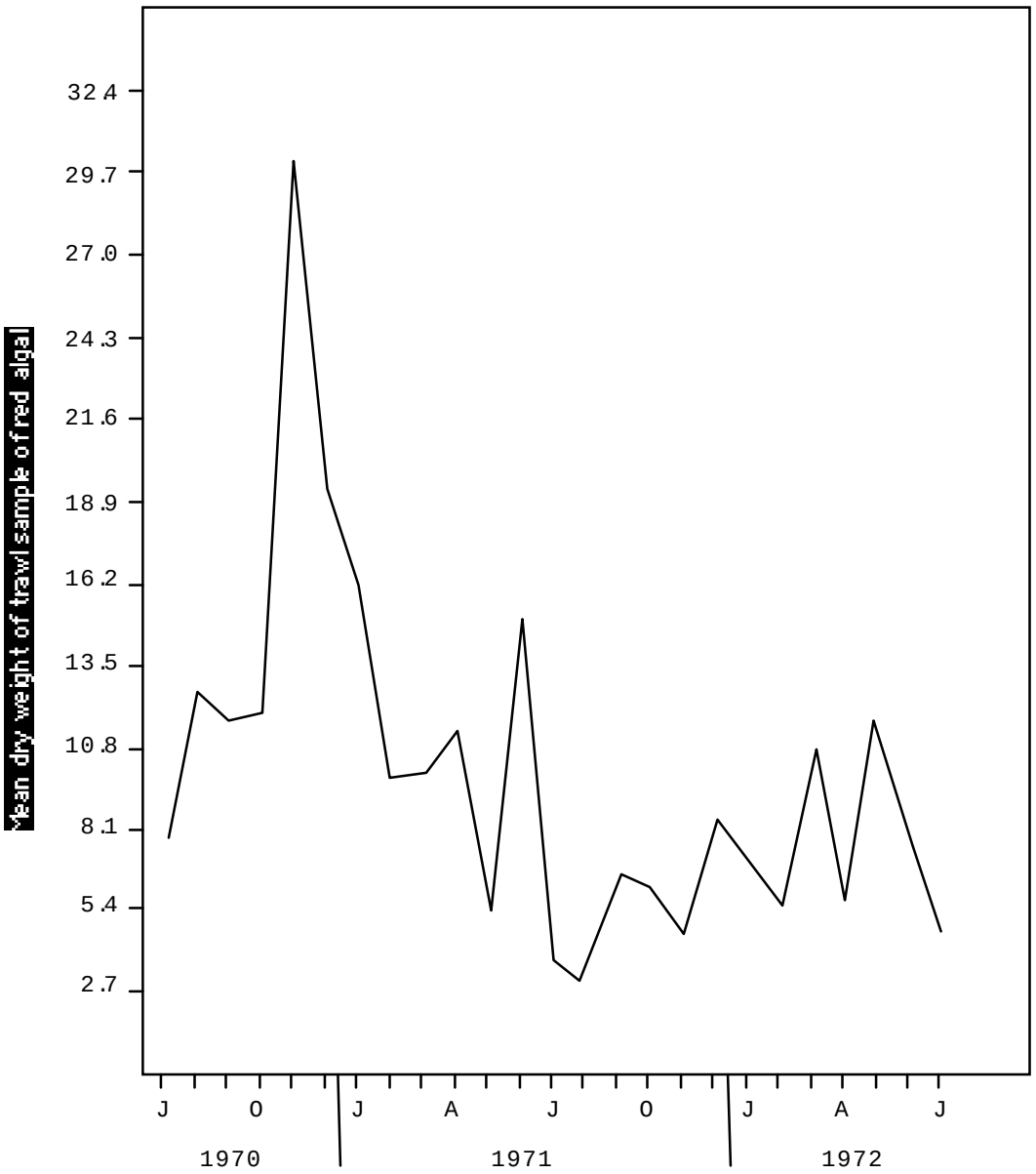

Figure 1. Mean dry weight in grams of trawl samples of the red algal complex at Card Sound for the time period July 1970 – July 1972.

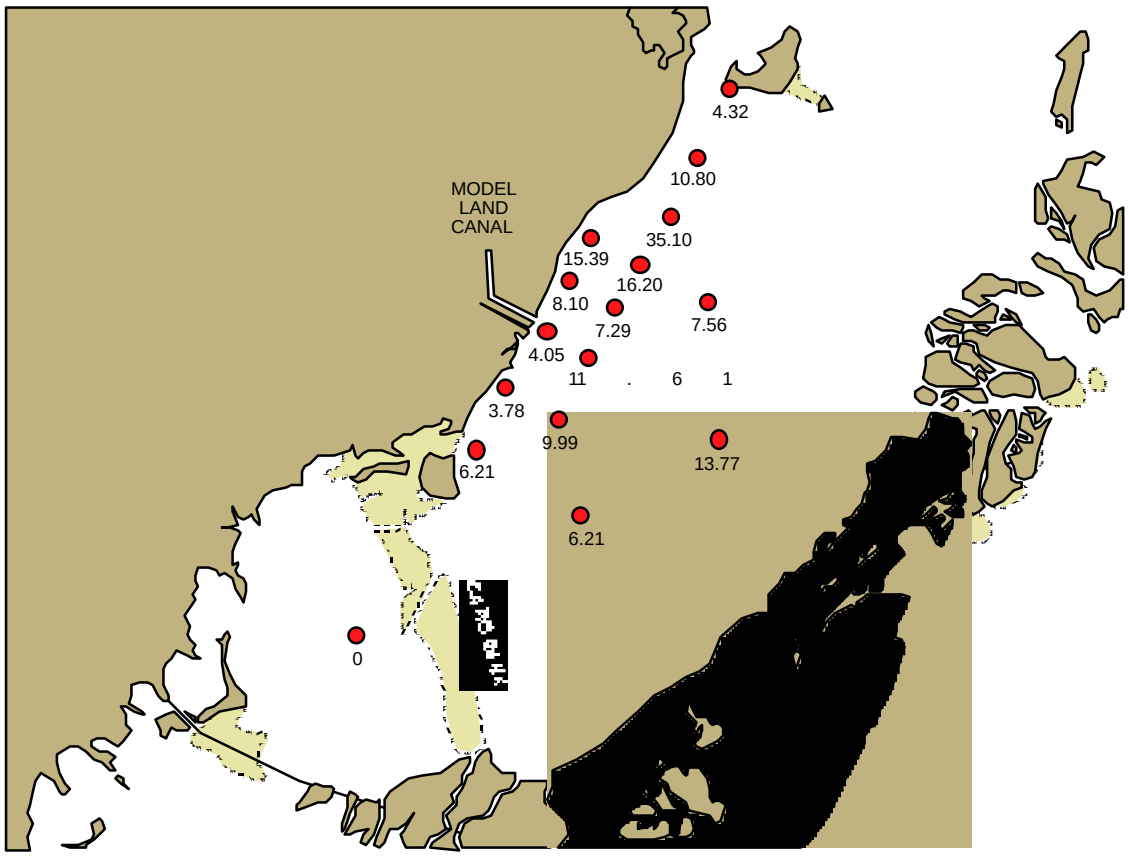

Figure 2. Mean standing crop in g dry weight/m^2 in 1971 in Card Sound, Florida, for the red algal complex.

Growth studies

The growth of *Laurencia poitei* was vigorous throughout the 9 month study period. Growth rates of the winter months did not appear to be different than summer months at the present growth rate of *Laurencia*. The outside tank at this time had a slightly higher growth rate than the inside tank. The most continuous set of measurements are those from April 12 to August 2 on the faster growing set of *Laurencia*. This included the 32 original specimens collected at various times was 4.2 mm/week outside and 5.8 per/week inside. The measured g dry weight/day of this total tip growth was 7.8 x 10^{-5}/tip/day outside and 1.09 x 10^{-4}/tip/day inside. Digenia simplex grew more rapidly in the outside tank conditions at 6.9 mm/week/branch tip, and 4.3 mm/week/branch tip inside.

The variation of growth with increasing temperature at the outside tank warmed in the spring and summer was not noticeable in either species, nor did growth decline. When the entire growth of each plant was measured by the proof paper method, one found that approximately 3 times more growth was recorded, due to a count of all branches and projections on the plant. Inside and outside both have about this same ratio. This latter measurement, of course, indicates a more realistic figure of total growth per plant. Plants measured for total growth of all branches showed an average growth inside of 1.66 cm/week/plant. The average plant would then produce 3.23 mg dry weight/day. In our preliminary observations of many individual plants from

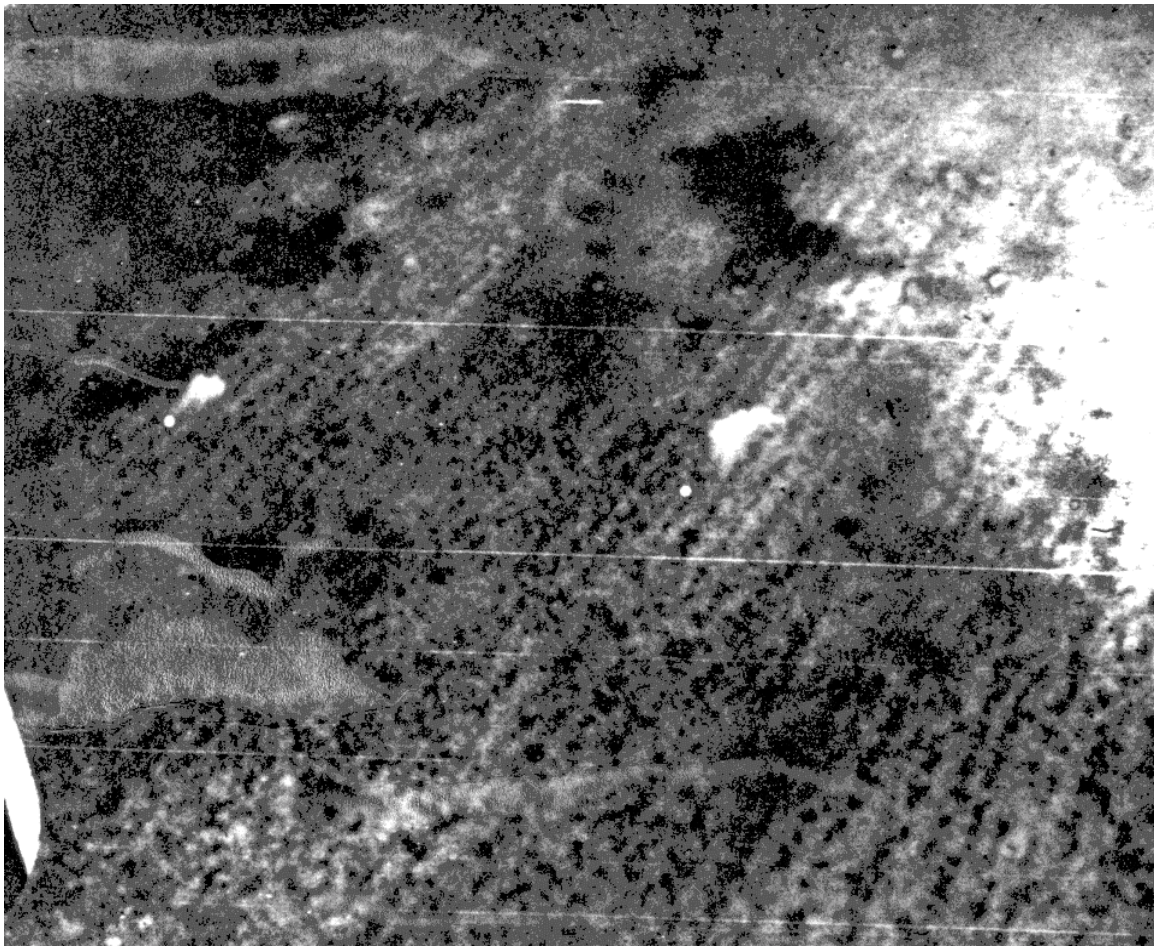

Figure 3. Parallel rows of *Laurencia poitei* in Card Sound indicating tidal current pattern. [SCANNED FROM A PHOTOCOPY OF THE ORIGINAL.]

Laurencia complexes and attached plants, the average plant weighed about 4 g. Total tip growth measurements were 1.66 cm (measured on 25 plants of 4 g) were 3.23 mg/day. Since the standing crop was 10.7 g/m^2 as a first approximation, the productivity of *Laurencia poitei* would then be 0.069 g (dry weight) /m^2/day or 25.19 g/m^2/year. Since Card Sound is approximately 37 km^2, this would make the annual productivity of *Laurencia* about 931 x 10^6 g dry weight in the total area.

DISCUSSION

The standing crop of the red algal complex in Card Sound, which consists chiefly of *Laurencia poitei* is 10.7 g dry weight/m^2/day as a first estimation from trawling figures, reconfirmed by diving observations and aerial photography of the area. Our productivity estimate for *Laurencia* of near 25 g dry weight/m^2/year for Card Sound. Present continuing laboratory and field studies of growth and standing crop should refine this figure. As a first approximation, since no estimate existed previously let us compare this to the productivity of *Thalassia testudinum*, which has been described as the dominant species in the benthic plant community. *Thalassia* productivity in Card Sound is 3811 g dry weight/m^2/year (Thorhaug and Stearns, in press), This figure appears higher than sea grass productivity some comparable figures of several workers including

Zostera (eelgrass) such as Dillon (1971) in Beaufort, North Carolina with a productivity of 346 g dry weight/m^2/year, and Phillips (1969) in Puget Sound finding 581 g/m^2/year. Our estimates of *Laurencia* productivity are limited by lack of field growth measurements, which are in progress at present.

Our original approximations, then indicate that in terms of dry weight of plant material contributed to the estuary, *Thalassia* is several orders of magnitude more productive, and that *Laurencia* may not contribute substantially to the detritus. Compared to northern estuarine estimates of productivity of algae, *Laurencia* is not extremely productive, such as *Laminaria* which produces up to 4400 g dry weight/m^2/year (Blinks, 1955). However, the importance of *Laurencia* may not be only in terms of grams of material produced but rather in its excellent protection as one of the few hiding places in this shallow (average depth 10 feet) embayment. Also the seasonal cycle of *Laurencia* appears to be a late fall and winter peak of productivity while *Thalassia* has a late spring peak of productivity. *Laurencia* may account for a necessary food source when other sources such as *Thalassia*, the green algae and mangrove detritus are at a low ebb. In addition, *Laurencia* may be a preferable food source and direct predation. may occur much more frequently than with *Thalassia*, perhaps allowing substantial amounts to directly enter the food web.

However, a major problem appears in discussing the food web of Card Sound at present. From the high *Thalassia* productivity, it would appear that this benthic grass is a major source of detritus, since few organisms have been to directly feed on the sea grass. However, detrital breakdown studies of the benthic plant community and its associated micro-organisms such as currently being conducted on mangrove detritus are definitely needed before the major pathways may be fully established.

Laurencia appears to be far more sensitive to environmental stresses such as heat, siltation and low salinities than does *Thalassia*. Areas of thermal effluent were *Thalassia* plants were able to recolonize to some extent in the winter months when the heat was no longer lethal, were more extensive than those in which large abundance of *Laurencia* reappeared. This greater sensitivity to heat only several degrees above mid-summer high was also demonstrated in laboratory studies (Thorhaug, unpublished). In areas where heavy siltation appeared due to digging of the canal *Laurencia* was killed in a larger area than was *Thalassia*.

In conclusion, this is a first report of one of the important benthic plants which has previously enjoyed scant attention. Field growth studies as well as detrital break down and use of *Laurencia* as a nutritional source are recommended.

ACKNOWLEDGMENTS

This work was sponsored by the United States Atomic Energy Commission, the Florida Power and Light Company and the National Oceanographic and Atmospheric Administration (Sea Grant).

The trawling data of Dr. Martin A. Roessler was deeply appreciated, as well as helpful discussions with him. Dr. Michael Neushul contributed helpful discussions of methods for algal culture. Dr. Harold Humm’s advice and encouragement was appreciated. Dr. Aldin Hine's kind assistance with systematic problem is also appreciated.

[NOT ALL REFERENCES WERE CITED OR LISTED.]

1. Biebl, R. 1962a. Protoplasmtich-okologische Untersuchungen and Mangrove Algen von Puerto Rico. Protoplasma 55: 572-606.

2. 1962b. Temperatturesistenz tropisher Meeresalgen (Verglichen nut jener von Algen temperierten Meeresgebieten). Bot. Mar. 4: 241-254.

3. Buffham, T. H. 1893. On the antheridia, etc. of some Florideae. J. Quekett Microscop. Club. 2(5): 291-305.

4. Dixon, P. S. 1963. The Rhodophyta: some aspects of their biology. Oceonogr. Mr. Biol. Ann. Rev. 1: 177-196.

5. Falkenberg, P. 1901. Die Rhodomelaceen des Golfes von Neapel und der angrenzenden Meeresabschnitte. Fauna u Flora d. Golfes v Neapel, Etc, 26.

6. Ferreira-Correia, M. M. 1969. Epifitas de *Digenia simplex* (Wulfen) C. Agorah no estado do ceara. Arq. Cien. Mar. 9(1): 63-69.

7. Grubb, V. M. 1925. The male organs of the Florideae. J. Linn. Soc. London. Bot. 47: 177-255.

8. Hansteen, B. 1892. Algeregioner og Algeformationen ved den norske Kyst. Nyt Mag. Naturvidensk 32: 341-363.

9. Heald, F. J. 1971. The production of organic detritus in a south Florida estuary. Sea Grant Tech. Bull. 6. 110 pp.

10. Humm, H. 1964. Epiphytes of the sea grass *Thalasia testudinum*, in Florida. Bull. Mar. Sci. 14(2): 306-341.

11. Kylin, H. 1923. Studien uber die Entwicklungsgeschichte der Florideen. Svensk. Vet. Akad. Handl. 64(11): 1-120.

12. 1928. Entwicklungsgeschichtliche Florideenstudien. Lunds Univ. Arsskr. N. F. II 24(4):1-94.

13. Mayer, A. G. 1914. The effects of temperature upon tropical marine organisms. Pap. Tortugas Lab., 6: 1-24.

14. Moore, H. B. 1972. In Press. Aspects of stress in a tropical marine environment. Advan. in Mar. Biol. Russel and C. M. Yonge (ed.).

15. Nadson, G. 1908. Veber den Einfluss der Lichtstarke auf die Farbung der Algen. Bull. Fard. Imp. Bot. St. Petersbourg 8: 122-143.

16. North, W. J. 1969a. The status of thermal discharges on the Pacific coast. Chesapeake Sci. 10(3 & 4): 139-144.

17. 1969b. Biological effects of a heated water discharge at Morro Bay, California. Proc. Int'l. Seaweed Symp. 6: 275-286.

18. Odum, W. E. 1970. Pathways of energy flow in a south Florida estuary. Ph.D. Dissertatlon, Univ. Miami, Coral Gables, Florida. 1-162 pp.

19. Rees, T. K. 1935. The marine algae of Longh Ine. J. Ecol. 23: 69-133.

20. Roessler, M. A. [NO OTHER INFORMATION IN ORIGINAL DOCUMENT.]

21. Ryther, J. H. 1963. Geographic variations in productivity. Vol. 2, Chap. 17, pp 347-38. In: M. N. Hill (ed.). The Sea. Interscience, New York.

22. Schmidt, O. C. 1929. Die marine vegetation der Azoren. Hedwigia 68: 327-346.

23. Ryther, J. H. 1969. Photosynthesis and fish production in the sea. Sci. 166: 72-76.

24. Tabb, D. C., D. L. Dubrow, R. B. Manning. 1962. The ecology of northern Florida Bay and adjacent estuaries. Fla. Bd. Conserv. Tech. Ser. 39: 1-81.

25. Tabb, D. C. and R. B. Manning. 1961. A checklist of the flora and fauna of northern Florida Bay and adjacent brackish waters of the Florida mainland collected during the period July, 1957 through September 1960. Bull. Mar. Sci. 11(4): 552-649.

26. Thorhaug, A. and R. Stearns. [1972? NO DATE IN ORIGINAL] An ecological study of *Thalassia testudinum* in unstressed and thermally stressed estuaries. Am. J. Bot. (In press).

27. Thorhaug, A., T. Devany, J. C. Bauer and S. Pepper. 1971. The effect of temperature on *Penicillus capitatus* survival in laboratory and field investigations. J. Phycol. 7(5): 5-6.

28. Thuret, G. 1855. Recherches sur la Fecondation des Fucacees et les antheridies des algues. II. Ann. Sci. Nat. Bot. IV. 3: 5-28.

29. Tripodi, G. 1967. Obsservazioni ecologiche su alcune alghe del golfo di Napoli in relazione alla loro distribuzione verticale. G. Bot. Ital. 101(1): 11-23.

30. Westbrook, M. A. 1928. Contributlons to the citology of tetrasporic plants of *Rhodymenia palmata* (L.) Grev. and some other Florideae. Ann. Bot. 42: 149-172.

31. 1935. Observations on nuclear structure in the Florideae. Beih. Bot. Centralbl. A. 53: 564-585.

32. Wolfe, D. A., G. W. Thayer, and R. B. Williams. 1972. Ecological effects of man's activities on temperate estuarine eelgrass communities. In: B. Ketchum (ed.) Critical Problems of the Coastal Zone. M.I.T. Press, Cambridge, Mass. (In pr